Intelligent Aviation System with Network Science & Transportation Analytics

CONTENTS

Abstract

Managing the increasing air traffic is becoming a significant worldwide challenge. Intelligent Transportation System (ITS) provides a solution to these problems with the help of new technologies. ITS is an integrated system that implements a broad range of communication, control, vehicle sensing, and electronics technologies to solve and manage traffic problems. ITS is very useful and important in the aviation sector as aviation has become an essential part of our society, driving economic, social, and cultural development worldwide. In India, the industry contributes around 1.5% of the country's GDP and supports eight million jobs. India is one of the fastest-growing aviation markets globally and is likely to become the third-largest market by 2030. We aimed towards analyzing the current scenario of flights in India by analyzing the existing datasets on the basis of different parameters with the help of data and network science.

1. INTRODUCTION

The Intelligent Transportation System (ITS) is an advanced application that aims to provide innovative services relating to different modes of transport and traffic management and enable users to be better informed and make safer, more coordinated, and 'smarter' use of transport networks[1]. Commercial airline safety has improved dramatically since the industry's birth over a century ago. Fatal accident rates for large scheduled jet airlines have fallen to the level where (along many dimensions) aviation is now the safest mode of commercial transportation [2]. Transportation planning in general, and planning for ITS in particular, are notable both for multiple goals and for multiple constituencies. In response to this policy environment, multicriteria decision analysis has often been utilized to evaluate alternative transportation investments [3]. ITS plays a key role when it comes to managing one of the most difficult challenges in the Aviation sector, which is global congestion. A couple of decades back, air travel had been a luxurious affair; playthings of the rich, especially in the developing countries. The scenario has changed drastically, today, airports all over the world are so crowded that it has led to unnecessary flight delays. Most flights seem full, terminals are always congested, and more importantly, the skies are overcrowded with an excessive number of aircraft.

Our project aims to improve the Indian aviation system by finding the dead spots so that the concerned authorities can build up new airports in places that have the required potential and can also improve connectivity.

Significant Research Highlights

- Generating a country-specific aviation network visualization
- Computing transportation analytics to study & estimate connectivity requirements
- Applying network centrality statistics, like degree, closeness & betweenness centrality
- Finding a set of shortest alternatives between source & destination airports based on a number of connecting flights
- Best route discovery based on the lat-long distance, cost, time or aggregated score between source & destination airports
- Finding alternative routes when some particular airports are unavailable

For our research, we used the dataset from OpenFlights (dated January 2017) [18] and the 2011 population census [19] data from Kaggle. With the help of Networkx and basemap, we plotted the data based on various parameters such as the number of flights, geographical location, and centrality.

2. RELATED WORK

There are several research works being conducted in the related area of building and analyzing intelligent transportation systems. The authors in [4] propose a framework of the smart transportation system, aiming to address the transportation problem in Karachi city. This study also highlights the current traffic situation of Karachi, its road conditions and capacity, vehicles condition, etc, and finally proposes a framework to develop a smart transportation system while keeping in mind the aforesaid traffic problems. The theory of complex networks was explored to study the network model of Guangzhou urban transport [5]. By analyzing the degree centrality index, betweenness centrality index, and closeness centrality index of nodes in the network, the level of the centrality of each node in the network is studied and the reliability of the network is determined by the stability of some key nodes. In paper [6], network planning constraints for interworking with existing networks are developed taking into account user preferences and usage scenarios as well as features of existing networks. In another contribution, the authors have presented a review of the state of the art on intelligent transportation systems [7]. Its main purpose is to study the achievements attained in the last years and to give an overview of possible directions towards future research. In [8], the contributors focus on the comparison and analysis of international ITS research and integrate the ITS technologies such as information, communications, computers, etc to design an integrated system of people, roads, and vehicles by utilizing advanced data communication technologies.

In another recent research, authors have aimed to elucidate various aspects of ITS, including the need, various user services, and technologies utilized [9]. The work was concluded by emphasizing the need for developing national ITS strategies. In [10] the authors have highlighted an in-depth survey of the related works, focusing on the design to understand CPS more precisely, and how it relates to different research fields, current concepts, and real-life applications. Further, it enumerates an extensive set of CPS challenges and opportunities, introducing visionary ideas, research strategies, and future trends expected by 2030 for critical future-oriented technological solutions, like cloud computing, the Internet of Things, and big data. In yet another work, authors have focussed on transport planning applications to identify traffic hotspot regions and a relative set of nodes acting as checkpoints [11]. These checkpoints can serve as monitoring stations for controlling the traffic hence improving sustainable mobility over roads. Finally, in another research initiative [12], the authors compared the performance of several machine learning algorithms applied to the problem of modeling air transport demand. Paper [13] presents an algorithm for finding all shortest routes from all nodes to a given destination in N-node general networks (in which the distances of arcs can be negative). If no negative loop exists, the algorithm requires $\frac{1}{2}M(N-1)(N-2)$, $1 < MN-1$, additions and comparisons. The existence of a negative loop, should one exist, is detected after $\frac{1}{2}N(N-1)(N-2)$ additions and comparisons. A new method is proposed for finding the shortest route in paper [14]. The shortest route is found by investigating a selection of routes from both the starting point and the terminal point. The selection of routes is decided dynamically by extending one by one the routes which have currently covered the least distance. Once a complete thorough route has been found, it has to be made certain that it is the minimum. In paper [15], an inductive procedure on nodes is given that requires $N(N-1)(N-2)$ comparison-addition operations to determine minimum routes between all nodes of a directed network. Arc distances may be negative. If negative cycles exist, however, the termination will occur when one such is found. The decomposition algorithm presented in the paper [16] is designed to facilitate the analysis of large networks. The basic idea is to decompose the network into parts, apply one of the existing (matrix) methods to each part separately, and then reunite the parts. In addition to greatly reducing the required amount of fast-access storage that is required, the algorithm generally appreciably reduces the required computer time, provided the network is not too small. In paper [17], the authors prove that the length of the shortest closed path through n points in a bounded plane region of area v is 'almost always' asymptotically proportional to $\sqrt{nv}$ for large n; and we extend this result to bounded Lebesgue sets in k–dimensional Euclidean space. The constants of proportionality depend only upon the dimensionality of the space and are independent of the shape of the region.

Motivated by the existing research, we have focussed on the following:

- analyzing the airways transportation system to assist the airport authorities to track the airplane movements and possible alternatives
- assisting passengers in selecting the best routes based on their preferences of cost, distance, and places to visit during the journey.

3. PROJECT UTILITY

Our project will assist the following four major categories of passengers:

a. **Airport Authority of India (AAI) -** This project will help them by providing them with a complete analysis of the present Aviation System so that they can easily look at the current situation of the airport network, i.e, the present dead spots, hotspots, population ratios, etc. and take the necessary steps to improve it.

b. **People in Critical Conditions** *(health emergency or other urgency)* - The people who are in some critical situation, can check the flights by giving more priority to time as compared to distance and expenses. They can check which flight will allow them to travel in less time.

c. **Businessman & Politicians -** This category includes the people for whom time is more valuable than expenses and thus they can check which route will take minimum time.

d. **General passengers -** Majority of the people search for ways to cut down their expenditures. Therefore our project will help them by providing the route which is the most cost-effective.

Since it includes different categories of people, it makes our project versatile. We are helping people to cut down their expenses whether it is in terms of time, cost, money, or a combination of all three.

4. TOOLS & TECHNOLOGIES

Our research initiative was implemented using Python which is considered as modular with fast execution and extensive support for different libraries. The following section shows the libraries and Application Programming Interfaces (APIs) used for our experimentation.

4.1. Language

- Python (Jupyter Notebook)

4.2. Libraries

- pandas: Library to work easily and efficiently with large dataframes
- numpy: Library to perform mathematical operations on large datasets
- networkx: Library for the creation, manipulation, and study of the structure, dynamics, and functions of complex networks.
- matplotlib: Library for creating visualizations
- basemap: Library for plotting 2D data on maps in Python.
- geopandas: Library to plot the geographical data
- geopy: Library to deal with geographical coordinates

4.3. API

- Mapbox: API used for Geolocation

5. PROPOSED ALGORITHM FOR AIR-ROUTE RECOMMENDATION

Table 1. Symbols and description

S.No.	Symbol	Description
1	V	Vertices (Airports)
2	E	Edges
3	$G(V, E)$	Graph of V vertices and E edges
4	src	Source
5	$dest$	Destination
6	$pref$	List of ordered preferences
7	$W_{i,j}$	Matrix storing weighted aggregated score for every connected node
8	INF	infinity
9	Q	Priority Queue
10	N_i	Neighbor set of Node i

The shortest distance is further computed on the basis of cost, time and distance. Algorithm 1 illustrates the proposed approach of computing a weighted aggregated score for finding preferred air-route. This involves all the three parameters, including cost, time and distance, preferentially as per the choice provided by the passenger. In our proposed algorithm, initially, we will take some inputs from the user, like, source, destination and preference order. Then we calculated the aggregated weight for all the edges in the graph. For this, we have assigned weights to the given preference order. Finally, in order to return the shortest path, we are backtracking from the destination and updating our path variable and then reversing the path to get the required source to the destination route.

Algorithm 1. *Proposed Algorithm for Finding Air Route for Weighted Aggregated Score*

Input: G(V, E), src, dest, pref

Procedure:

```
E := {e_{i,j} | i, j ∈ V, i != j}          #set of edges
    for each i in G:
        for each j in G - {i}:
            W_{i,j} = 0                     #W is a matrix
    end-for

    #Calculate the aggregate weight
    w1 := 0.6
    w2 := 0.3
    w3 := 0.1

    for each i in G:
        for each j in G - {i}:
            W_{i,j} := w1 * e_{i,j}(pref[0]) + w2 * e_{i,j}(pref[1]) + w3 * e_{i,j}(pref[2])
        end-for
    end-for

  # precomputation to find the best route
  for each i in G:
    shortest[i] := INF
    previous[i] := NULL
  end-for

  shortest[src] := 0
  Push {0,src} into Q                       #Q is a Heap Queue

  while x in Q:
     U := min(Q(w, x))                      #w is aggregate weight of node x
     Q := Q - U   #dequeued
     for each neighbour n ∈ N_U:
         temp = shortest[U] + W_{U,n}
            if temp < shortest[n]:
```

```
                shortest[n] := temp
                previous[n] := U
                Push {shortest[n], n} into Q    #enqueued
            end-if
        end-for
    end-while

    path := {}
    cur := D
    while cur <> NULL:
        path := path U {cur}
        cur := prev[cur]
    end-while

    path := reverse(path)    #path from s to d
```

Output: Path

Table 2. Weights given according to preference

S.No.	Preference	Weight
1	Highest	0.6
2	Medium	0.3
3	Lowest	0.1

Subsequently, we have updated the weights of all the edges to the recently calculated aggregate weight. Now in order to find out the shortest route, we first initialize the shortest distance from the source to all the vertices as “infinity”. After that, we are maintaining a heap queue which will assist us in finding out the shortest path. In that, if the sum of the current weight and the neighbor weight is less than the precomputed value, then we will update it and add the vertex to our path.

Table 3. Acronyms used and their full form

S.No.	Acronyms	Full-Form
1	ITS	Intelligent Transportation System
2	$IATA$	International Air Transport Association
3	$ICAO$	International Civil Aviation Organization

4	Lat	Latitude
5	$Long$	Longitude
6	Alt	Altitude
7	$Tz\ database\ time$	Timezone in "tz" (Olson) format, eg. "America/Los_Angeles".
8	GDP	Gross domestic product
9	AAI	Airport Authority of India
10	PPA	Population per unit area

6. IMPLEMENTATION & RESULTS

We started looking up for an appropriate dataset for our project and landed on the OpenFlights dataset in which there are 10 attributes, namely, ID, Name, City, Country, IATA, ICAO, Lat, Long, Alt, Timezone, DST, Tz database time zone, type, source. Then we started implementing the core functionalities.

Execution Steps:

6.1. Airport Network Visualization

In order to visualize the connectivity of all the airports in India, which are around 150 commercial airports, and envision their degree of connectivity, we took the help of some Python libraries, specifically, Basemap and Networkx.

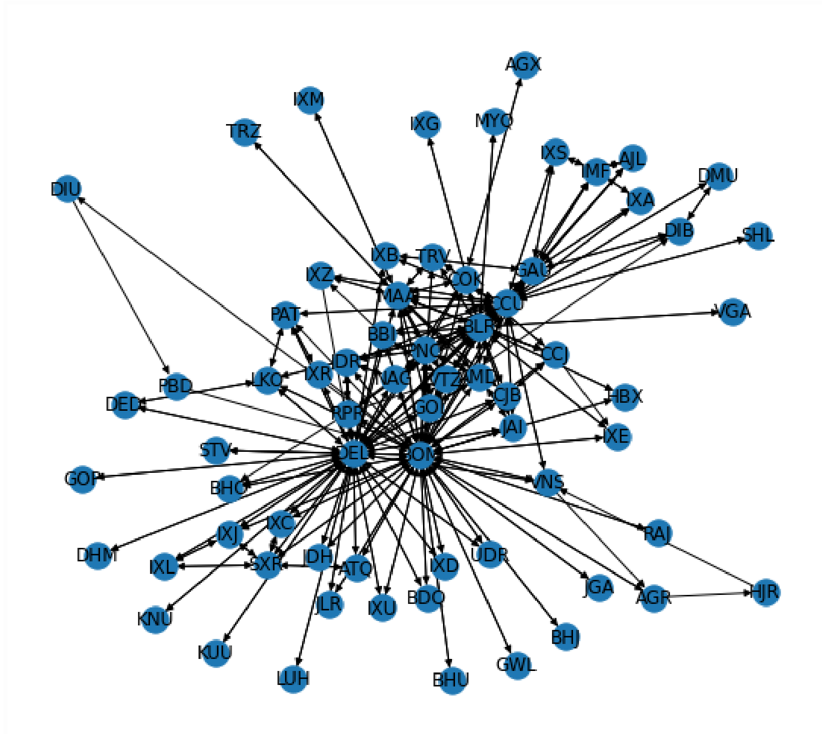

Figure 1. Connectivity of all Indian airports drawn using NetworkX

From figure 1, we can visualize the connectivity of different airports in India. Here, the nodes represent the airports and the directed edges represent the routes between airports.

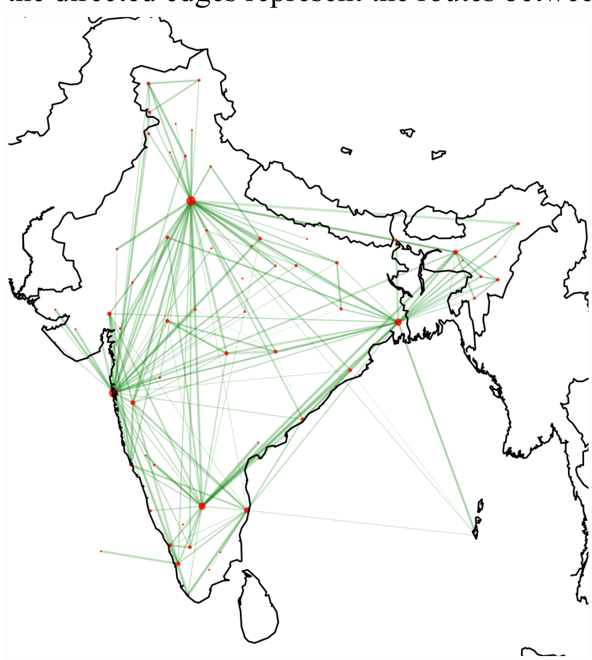

Figure 2. Geo-map visualization with node size representing relative number of flights in and out of the airports using NetworkX and Basemap

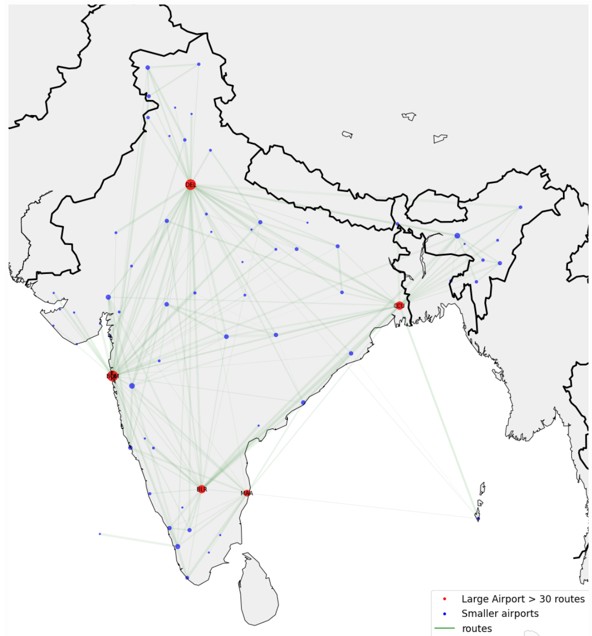

Figure 3. Network graph of flight routes grouped into small and large airports

6.2. Statistical Analytics

i. Airport-Population-Area Ratio: We used the statewise population dataset from the last conducted census (2011) [12]. Since the airports' dataset didn't have the states included in it, we used Mapbox's reverse geocoding API to fetch their states from their coordinates. Firstly, we calculated the population-residing per unit-area (PPA), as expressed in equation (1). Subsequently, we used the PPA ratio to find out the measure of the requirement of airports in a particular area, as highlighted in equation (2).

$$PPA = \frac{Population}{Area(km^2)} \tag{1}$$

$$Airports\_to\_PPA = \frac{Number\ of\ Airports}{PPA} \tag{2}$$

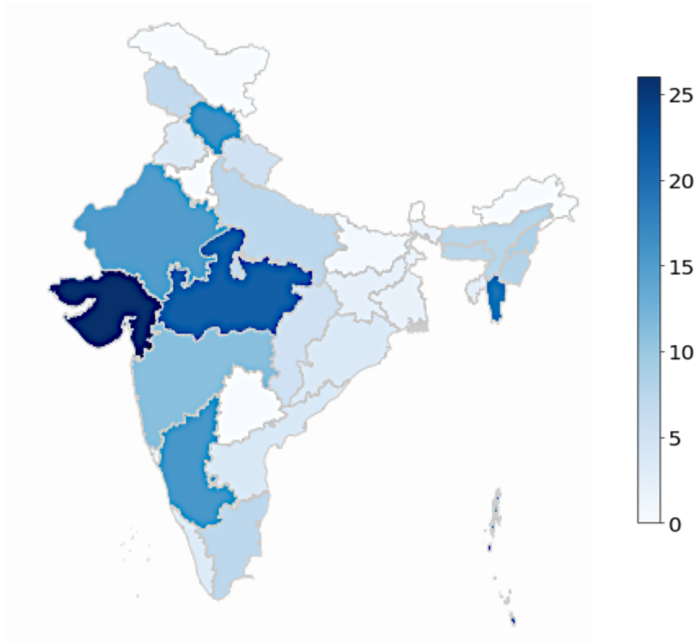

Figure 4. Degree Centrality of airports in India

From the above result, it is visible that Gujarat and Madhya Pradesh have a balanced ratio of airports, area, and population as compared to the other states whereas, the states in lighter shade need more airports.

ii. Network Centrality Statistics: In order to figure out the various hubs in the previously constructed network, we calculated three different centralities, namely, Degree Centrality, Closeness centrality and Betweenness centrality for each node (airport).

- **Degree Centrality:** The degree centrality of a node in a graph is simply a count of the number of edges that connect to it. In equation (3), d_i refers to the degree of node i in a network with n nodes.

$$D_i(g) = \frac{d_i}{n-1} \tag{3}$$

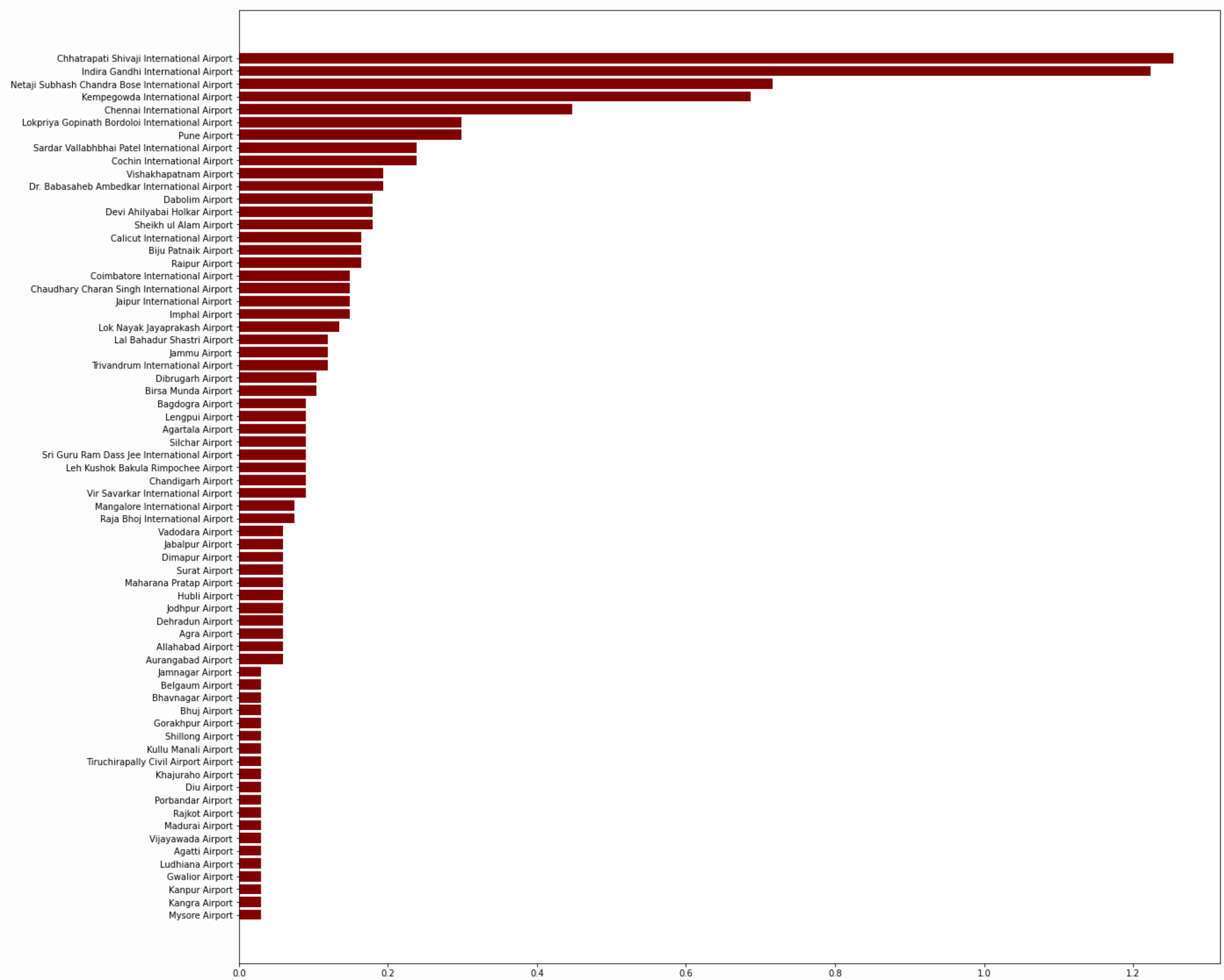

Figure 5. Degree centrality of airports in India

From figure 5, as shown above, we can infer that Chhatrapati Shivaji International Airport and Indira Gandhi International Airport are the most widely connected airports whereas airports like Mysore Airport and Kanpur airport are least connected in India.

- **Closeness Centrality:** Closeness centrality indicates how close a node is to all other nodes in the network. It is calculated as the average of the shortest path length from the node to every other node in the network. In equation (4), the formula for closeness centrality is illustrated with $l(i, j)$ referring to the shortest path between nodes i and j, respectively.

$$Cl_i(g) = \frac{n-1}{\sum_j l(i,j)} \tag{4}$$

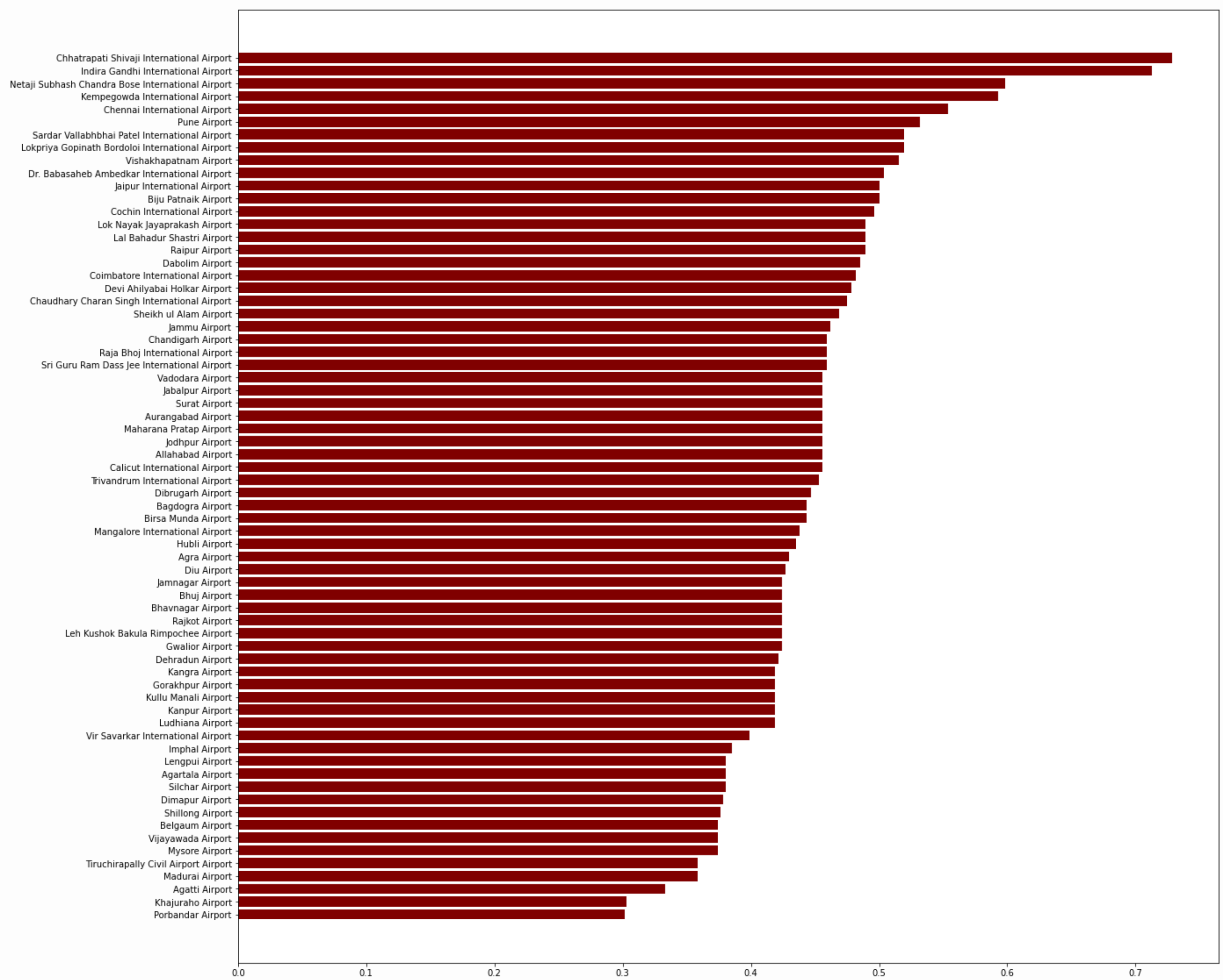

Figure 6. Closeness centrality of airports in India

The graph as shown in figure 6, indicates that Chhatrapati Shivaji International Airport and Indira Gandhi International Airport are the airports which are most close to all the other airports in India.

- **Betweenness Centrality:** Betweenness centrality is a widely used measure that captures a person's role in allowing propagation to pass from one part of the network to the other. The expression of the centrality metric is provided in equation (5), where $l_h(i, j)$ refers to the shortest path between a pair of nodes, containing the node h in-between as an intermediate or bridging node.

$$B_h(g) = \frac{\sum_{i,j \neq h} \frac{l_h(i,j)}{l(i,j)}}{C_2^{n-1}} \quad (5)$$

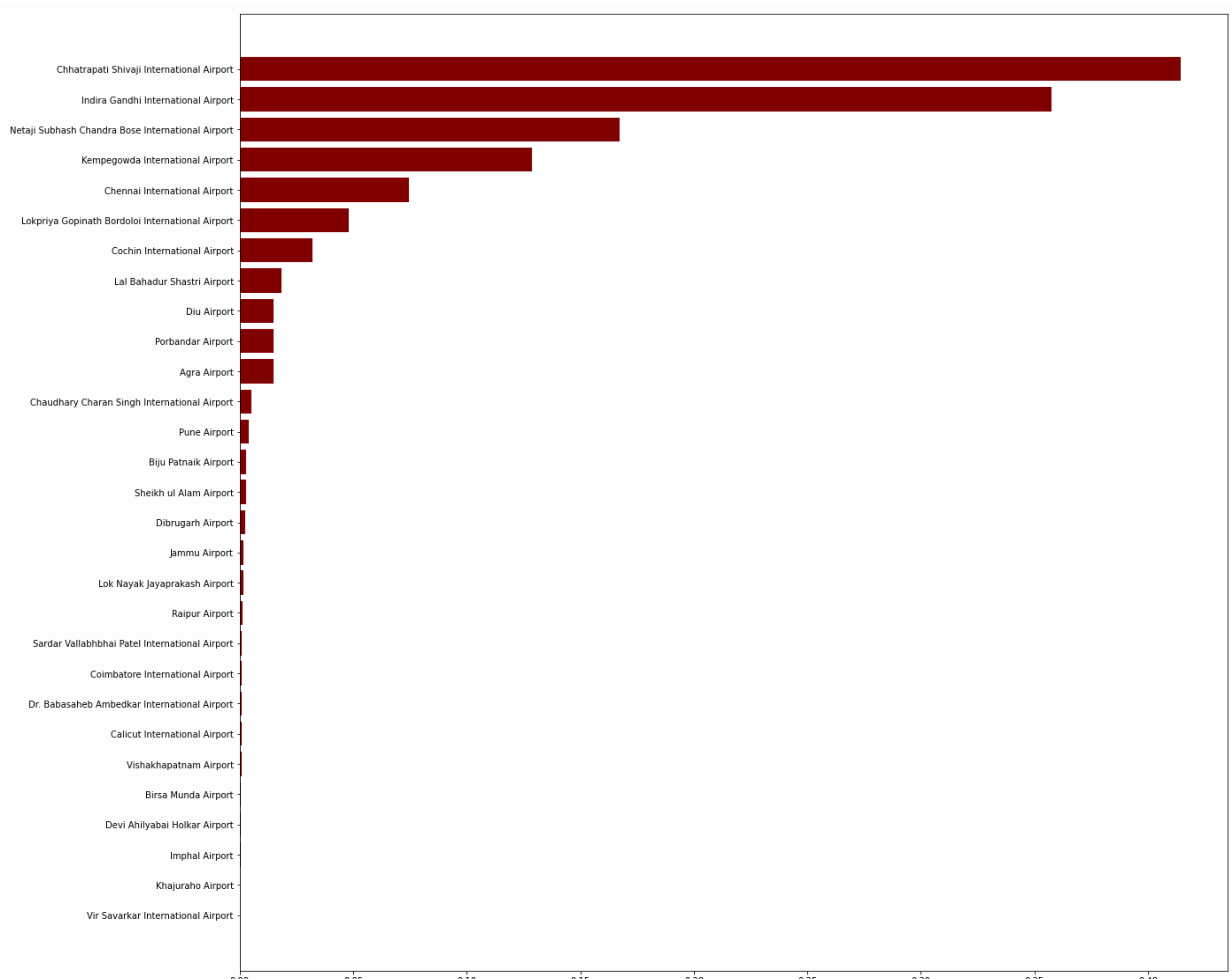

Figure 7. Betweenness centrality of airports in India

From the figures (4-7), it is apparent that the top 5 airports act as hubs at which maximum inflow outflow takes place and therefore, the concerned authorities should ensure their proper functioning. There should be enough aviation staff to handle critical situations. Also, safety and security, along with a hygienic environment, should be given priority to prevent any mishaps or disease outbreaks.

6.3. Transportation Analytics

We used different functions of the networkx library in order to find out the shortest routes and different alternatives between a source and destination airports, as provided by the passengers. For our experimentation, we have taken Veer Savarkar International Airport (IXZ) as the source and Khajuraho Airport (HJR) as the destination, to illustrate a case study. We displayed the shortest route on the basis of probable intermediate places and distance covered between the endpoints, i.e. source and destination airports.

a. Jumps (connecting flights)

Our experimentation revealed five such routes that are the shortest alternatives from the taken source to destination as shown below. Here, the shortest routes are basically computed in terms of the number of hops or links, thereby showing the intermediate places as *connecting flights*.

```
['IXZ', 'CCU', 'BOM', 'AGR', 'HJR']
['IXZ', 'DEL', 'BOM', 'AGR', 'HJR']
['IXZ', 'MAA', 'BOM', 'AGR', 'HJR']
['IXZ', 'CCU', 'VNS', 'AGR', 'HJR']
['IXZ', 'DEL', 'VNS', 'AGR', 'HJR']
```

Figure 8. All shortest routes from IXZ to HJR on the basis of connecting flights

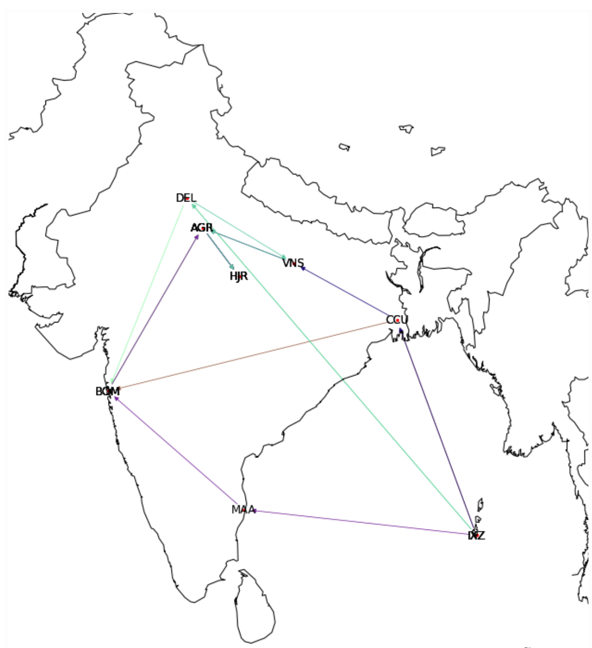

Figure 9. Shortest routes between source and destination on the basis of connecting flights

Figure 9 shows the various shortest routes obtained on the basis of connecting flights between the given source, IXZ and destination, HJR. The various paths are as follows:
['IXZ', 'CCU', 'BOM', 'AGR', 'HJR']
['IXZ', 'DEL', 'BOM', 'AGR', 'HJR']
['IXZ', 'MAA', 'BOM', 'AGR', 'HJR']
['IXZ', 'CCU', 'VNS', 'AGR', 'HJR']
['IXZ', 'DEL', 'VNS', 'AGR', 'HJR']

b. Lat-Long Distance

To find the shortest route on the basis of latitude-longitude distance, we calculated the distance between a pair of airports with the help of their latitude and longitude. After that, we calculated the shortest route with the help of the weighted graph.

Figure 10. Route discovered between source and destination airports on the basis of lat-long distance

According to figure 10, we can observe that the shortest route between AJL and COK, on the basis of lat-long distance is ['AJL', 'CCU', 'MAA', 'COK'].

c. Cost

To find the shortest route on the basis of cost, we first generated a random set of costs for each edge through the following formula:

$$C_{ij} = d_{ij} \times RNG(d_{min}, d_{ij}) \qquad (6)$$

After that, we normalized the costs between 3000 and 30,000 and calculated the shortest route with the help of the weighted graph.

Figure 11. Route discovered between source and destination airports on the basis of cost

In total, there are 8 paths from AJL to COK as found out from our algorithm, which are as follows, along with their costs:
['AJL', 'CCU', 'BLR', 'COK'] => 3644.86 + 9226.84 + 3378.30 = 16250
['AJL', 'GAU', 'BLR', 'COK'] => 3221.55 + 14427.56 + 3378.30 = 21027.41
['AJL', 'CCU', 'BOM', 'COK'] => 3644.86 + 16287.17 + 9568.90 = 29500.93
['AJL', 'GAU', 'BOM', 'COK'] => 3221.55 + 7473.64 + 9568.90 = 20264.09
['AJL', 'CCU', 'DEL', 'COK'] => 3644.86 + 5029.71 + 26616.44 = 35291.01
['AJL', 'GAU', 'DEL', 'COK'] => 3221.55 + 13474.00 + 26616.44 = 43311.99
['AJL', 'CCU', 'MAA', 'COK'] => 3644.86 + 11385.40 + 4021.93 = 19052.19
['AJL', 'CCU', 'PNQ', 'COK'] => 3644.86 + 19171.10 + 4792.93 = 27608.89

The values on the right of each path displays the total cost of each path. Therefore, on the basis of above values we can observe that the path ['AJL', 'GAU', 'BLR', 'COK'] is the most optimal in terms of cost, which is the same as represented by the graph in figure 10.

d. Time

To find the shortest route on the basis of time, similar to cost, we first generated a random set of values for each edge through the following formula:

$$T_{ij} = d_{ij} \times RNG(d_{min}, d_{ij}) \quad (7)$$

After that, we normalized the time values between 1 hr and 6 hrs and calculated the shortest route with the help of the weighted graph.

Figure 12. Route discovered between source and destination airports on the basis of time

In total, there are 8 paths from AJL to COK as found out from our algorithm, which are as follows, along with their time:

['AJL', 'CCU', 'BLR', 'COK'] => 5.89 + 3.09 + 5.85 = 14.83
['AJL', 'GAU', 'BLR', 'COK'] => 5.97 + 4.67 + 5.85 = 16.49
['AJL', 'CCU', 'BOM', 'COK'] => 5.89 + 4.15 + 5.06 = 15.1
['AJL', 'GAU', 'BOM', 'COK'] => 5.97 + 2.89 + 5.06 = 13.92
['AJL', 'CCU', 'DEL', 'COK'] => 5.89 + 4.84 + 3.81 = 14.54
['AJL', 'GAU', 'DEL', 'COK'] => 5.97 + 4.89 + 3.81 = 14.67
['AJL', 'CCU', 'MAA', 'COK'] => 5.89 + 4.55 + 5.72 = 16.16
['AJL', 'CCU', 'PNQ', 'COK'] => 5.89 + 3.86 + 5.64 = 15.39

The values on the right of each path displays the total time of each path. Therefore, on the basis of above values we can observe that the path ['AJL', 'GAU', 'BOM', 'COK'] is the most optimal in terms of time, which is the same as represented by the graph in figure 11.

e. Aggregate

To find the shortest route on the basis of a combination of all factors, like distance, cost and time, we will first take their preference order and allot them weights accordingly. The one with the highest preference will be given a weight of 0.6(w1), the one with medium priority will be given a weight of 0.3(w2) and the one with the lowest priority will be given the weight of 0.1(w3). Then, an overall score is generated for each edge using the following formula:

$$Score_{ij} = w1 * first + w2 * second + w3 * third \tag{8}$$

Here, first represents the parameter value with the highest preference, second represents the value with medium preference and the third represents the value with the lowest preference.

On the basis of the obtained score for each edge, we calculated the most optimal path from the given source to the destination.

Figure 13. Route discovered between source and destination airports on the basis of aggregate values

From figure 12, as shown above, we can observe that the most optimal path between AJL and COK, on the basis of aggregate values, is ['AJL', 'GAU', 'BOM', 'COK'] and its score is 1.56.

Therefore, we first visualized the connectivity among various airports in India and then computed the airport-population-area ratio, which acts as a measure of requirement of airports in an area. We also found the shortest paths between source and destination on the basis of connecting flights and lat-long distance. Along with this, shortest routes were also calculated on the basis of cost and expenses involved in traveling from source and destination.

6.4 Global Study

So far we have done our research for India only. Now we are applying all our research methods to the world map so that we can have a broader view and would be able to visualize all the connected flight routes globally and would also be able to assist users to find out the best route on the basis of time, cost, distance, and aggregated score taking any source and destination into consideration.

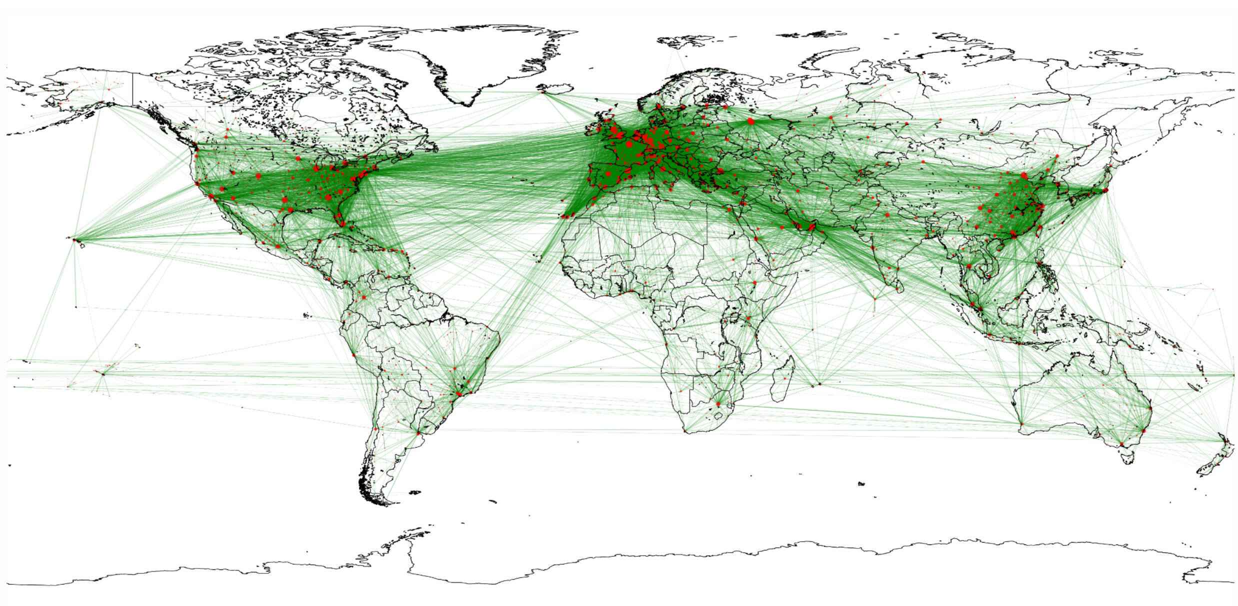

Figure 14. Geo-map visualization with node size representing a relative number of flights in and out of the airports using NetworkX and Basemap

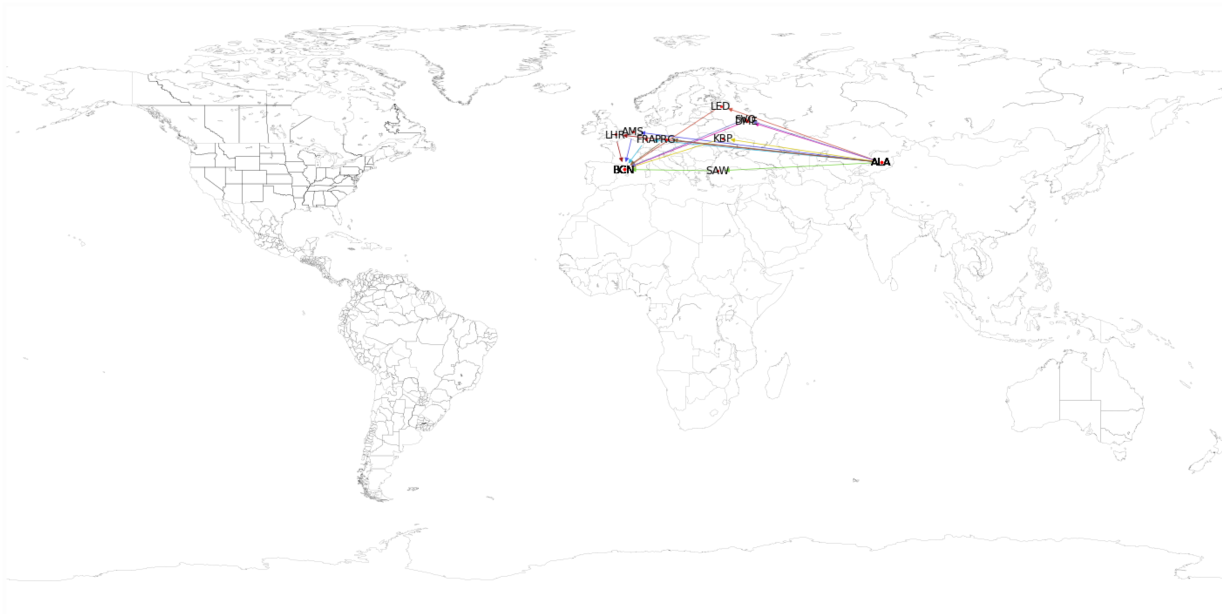

Figure 15. Shortest routes between source and destination airports on the basis of connecting flights

Figure 15 shows all the possible shortest paths from Almaty International Airport (ALA) to Barcelona Airport (BCN) on the basis of jumps. According to the figure, there are 9 shortest possible routes between the taken source and destination.

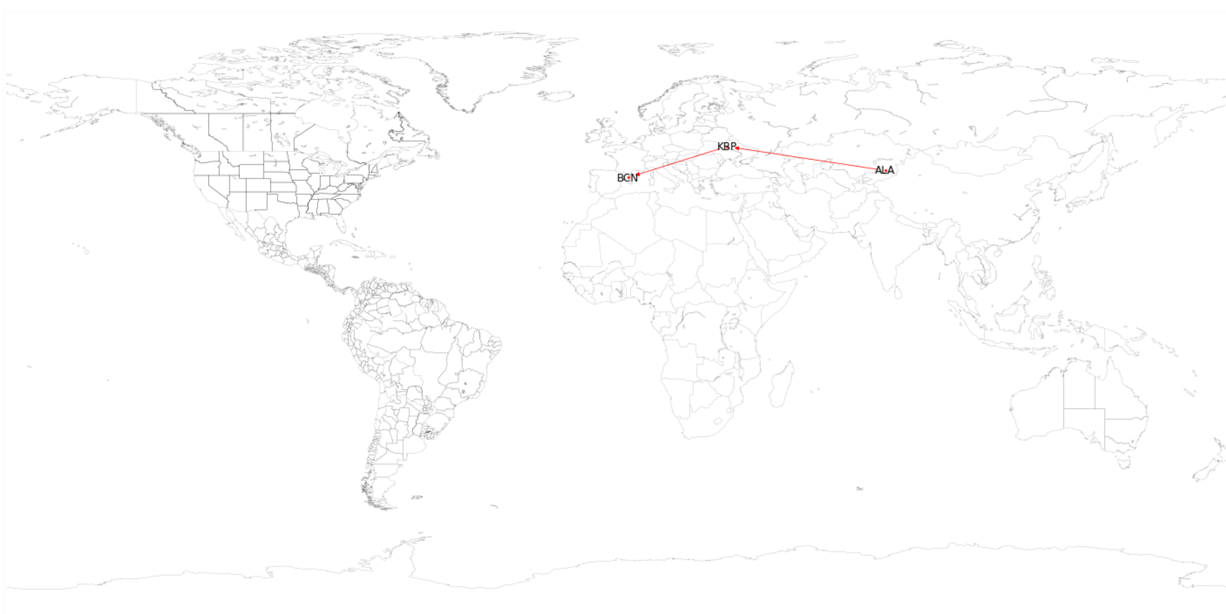

Figure 16. Shortest routes between source and destination airports on the basis of distance

Figure 16 shows all the possible shortest paths from Almaty International Airport (ALA) to Barcelona Airport (BCN) on the basis of distance. According to the figure, there is only 1 shortest possible route between source and destination.

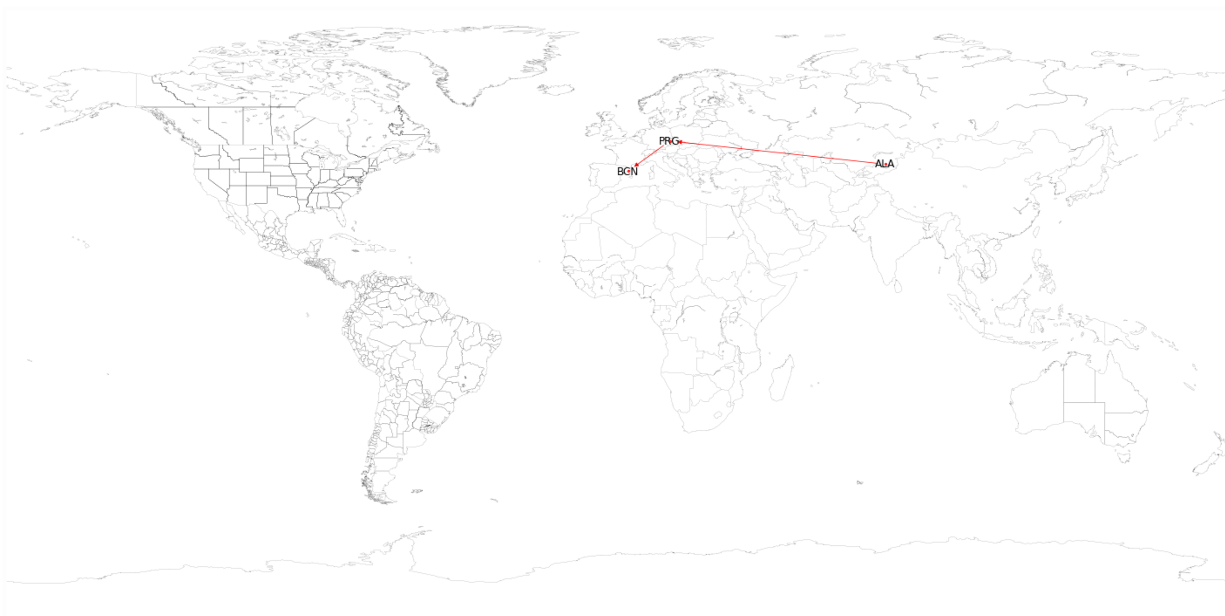

Figure 17. Shortest routes between source and destination airports on the basis of cost

According to figure 17, we can observe that the shortest route between BCN and ALA, on the basis of cost is ['BCN', 'PRG', 'ALA'].

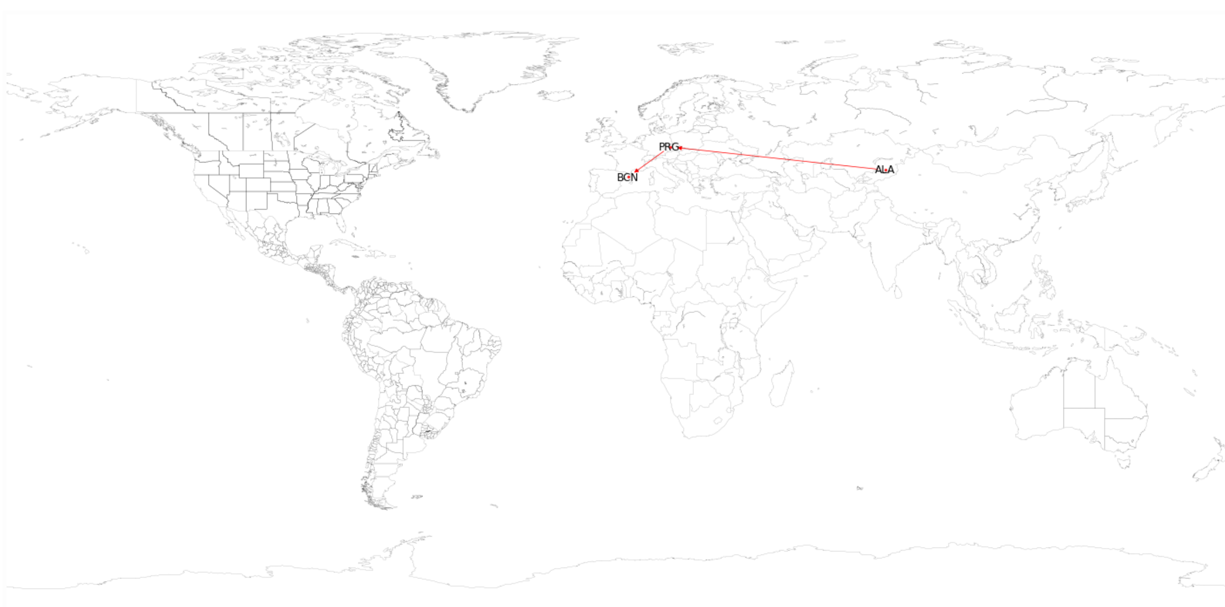

Figure 18. Shortest routes between source and destination airports on the basis of time

According to figure 18, we can observe that the path ['AJL', 'PRG', 'BCN',] is the most optimal path in terms of time.

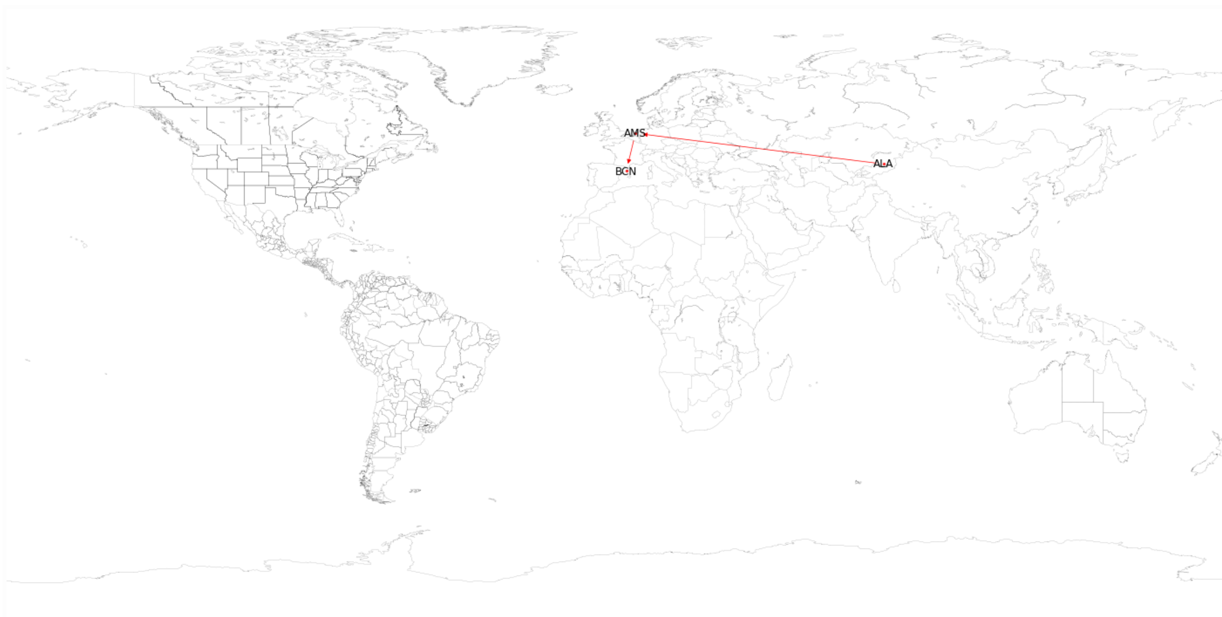

Figure 19. Shortest routes between source and destination airports on the basis of aggregated values

From figure 19, as shown above, we can observe that the most optimal path between ALA and BCN, on the basis of aggregate values is ['ALA', 'AMS', 'BCN']

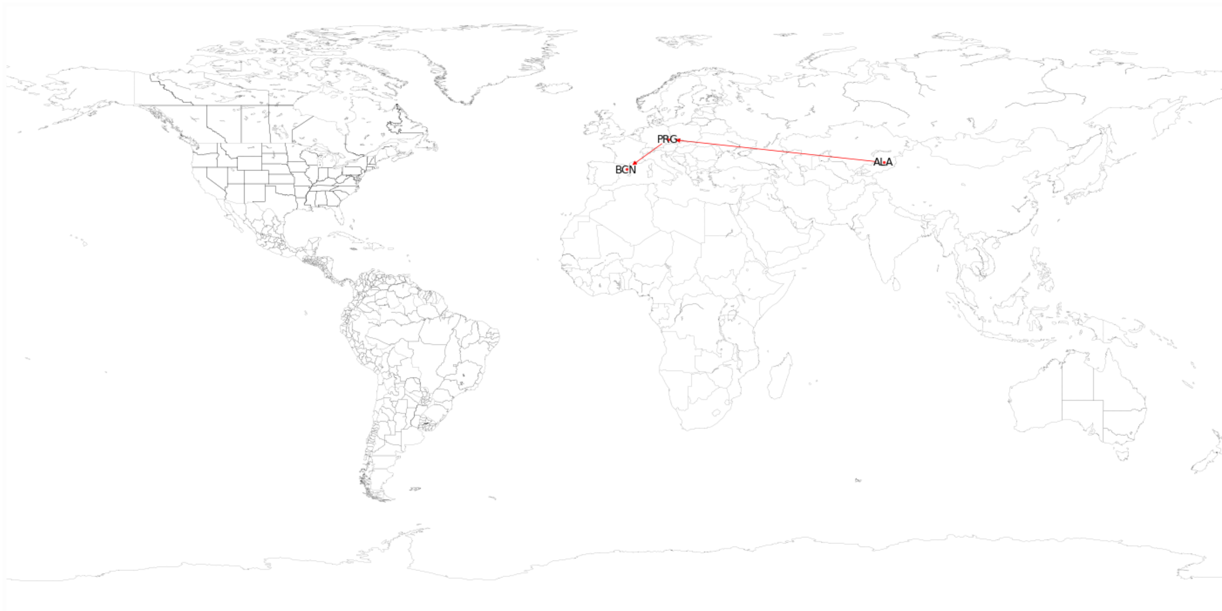

Figure 20. Shortest routes between source and destination airports on the basis of distance, when a particular airport cannot be used

From figure 20, we can observe that the new alternative route on the basis of distance is ['ALA', 'PRG', 'BCN'] when Boryspil International Airport (KBP) is not available due to some underlying reason.

7. CONCLUSION

ITS is emerging as an ever-demanding application that focuses on providing improved roadways, railways, and airways services with the fundamental motives of safety, comfort, and ease in mobility with intelligent decision making. In our research, we have performed an analysis of the airways transportation system for assisting the airport authorities in managing the flight movements and tracking all possible alternatives by visualizing the connectivity among all the airports in India and calculating various centralities. It indicated that the Chhatrapati Shivaji International Airport and Indira Gandhi International Airport act as hubs.

For transportation analysis, we found 5 paths with the shortest distance between the given source, IXZ and destination, HJR on the basis of connecting flights and 1 path on the basis of lat-long distance between the same. After this, we also calculated the optimal routes between AJL and COK, on the basis of cost and time. On the basis of cost, we got the path ['AJL', 'CCU', 'BLR', 'COK'], where cost is 16250 and on the basis of time, we got ['AJL', 'GAU', 'BOM', 'COK'], where the time is 13.92. Then a path is also calculated by aggregating all the factors which are distance, cost, and time by giving them weights according to their preference level. We have also provided alternative routes when particular airports are unavailable.

8. FUTURE PLAN

- To design a web application that can provide a smart interface to display all analytics in the form of an integrated dashboard to better assist the passengers to locate routes and multiple alternatives between the source and destination airports.
- To add more features for improving our analysis, like air-traffic dead spots and hotspots.

9. REFERENCES

[1] J. Zhang, F. Wang, K. Wang, W. Lin, X. Xu and C. Chen, "Data-Driven Intelligent Transportation Systems: A Survey," in IEEE Transactions on Intelligent Transportation Systems, vol. 12, no. 4, pp. 1624-1639, Dec. 2011, doi: 10.1109/TITS.2011.2158001..

[2] Oster Jr, C. V., Strong, J. S., & Zorn, C. K. (2013). Analyzing aviation safety: Problems, challenges, opportunities. Research in transportation economics, 43(1), 148-164.

[3] Levine, J., & Underwood, S. E. (1996). A multiattribute analysis of goals for intelligent transportation system planning. Transportation Research Part C: Emerging technologies, 4(2), 97-111.

[4] Aamir, M., Masroor, S., Ali, Z. A., & Ting, B. T. (2019). Sustainable framework for smart transportation system: a case study of karachi. Wireless Personal Communications, 106(1), 27-40.

[5] Wang, K., & Fu, X. (2017, May). Research on centrality of urban transport network nodes. In AIP conference proceedings, vol. 1839, no. 1, p. 020181, AIP Publishing LLC.

[6] K. A. Kastell, "Network planning for intelligent transportation systems based on existing wireless networks," 2013 5th International Congress on Ultra Modern Telecommunications and Control Systems and Workshops (ICUMT), 2013, pp. 28-32, doi: 10.1109/ICUMT.2013.6798400.

[7] Figueiredo, L., Jesus, I., Machado, J. T., Ferreira, J. R., & De Carvalho, J. M. (2001, August). Towards the development of intelligent transportation systems. In ITSC 2001. 2001 IEEE intelligent transportation systems. Proceedings (Cat. No. 01TH8585), pp. 1206-1211

[8] An, S. H., Lee, B. H., & Shin, D. R. (2011, July). A survey of intelligent transportation systems. In 2011 Third IEEE International Conference on Computational Intelligence, Communication Systems and Networks, pp. 332-337.

[9] Johann Andersen, Steve Sutcliffe, Intelligent Transport Systems (ITS) - An Overview. IFAC Proceedings, volume 33, issue 18, 2000.

[10] Mazen Juma, Khaled Shaalan, 4 - Cyberphysical systems in the smart city: challenges and future trends for strategic research, Editor(s): Aboul Ella Hassanien, Ashraf Darwish, In Intelligent Data-Centric Systems, Swarm Intelligence for Resource Management in Internet of Things, Academic Press, 2020

[11] S. Jain, A. Sinha, Social network sustainability for transport planning with complex interconnections, Sustainable Computing: Informatics and Systems, Elsevier, Volume 24, 2019

[12] Wild, G., Baxter, G., Srisaeng, P., & Richardson, S. (2021). Machine Learning for Air Transport Planning and Management. arXiv preprint arXiv:2112.01301

[13] Yen, J. Y. (1970). An algorithm for finding shortest routes from all source nodes to a given destination in general networks. Quarterly of Applied Mathematics, 27(4), 526-530.

[14] Nicholson, T. A. J. (1966). Finding the shortest route between two points in a network. The computer journal, 9(3), 275-280. */

[15] Dantzig, G. B. (1966). All shortest routes in a graph. STANFORD UNIV CA OPERATIONS RESEARCH HOUSE.

[16] G. Mills, (1966) A Decomposition Algorithm for the Shortest-Route Problem. Operations Research 14(2):279-291.

[17] Beardwood, J., Halton, J., & Hammersley, J. (1959). The shortest path through many points. Mathematical Proceedings of the Cambridge Philosophical Society, 55(4), 299-327. doi:10.1017/S0305004100034095

[18] OpenFlights Dataset (dated January 2017, last accessed on February 2022) - https://openflights.org/data.html

[19] Census 2011 dataset - https://www.kaggle.com/gokulrajkmv/indian-statewise-data-from-rbi